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PAPER BIRCH

Its Characteristics, Properties, and Uses

A REVIEW OF RECENT LITERATURE - by Matti J. Hyvarinen

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Cover picture: A pure stand of paper birch. Stands such as these have the potential for producing a high proportion of saw logs and veneer bolts.

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Paper Birch: Its Characteristics, Properties, and Uses

A Review of Recent Literature

Matti J. Hyvarinen

Paper birch, *Betula papyrifera* Marsh., has recently become one of the most abundant species in the Lake States. In Minnesota it ranks third in growing stock volume, after aspen and jack pine (Stone 1966).¹

This fast-growing, short-lived tree is attacked by many enemies and will not store on the stump. But because of its generally

small size, the annual cut is only about a sixth of the desirable cut.

A better knowledge of the species — the resource, silvics, wood quality and properties, and products — should stimulate more extensive use. This paper reviews recent literature on these subjects and points out areas in which additional research is needed.

Resources

The aspen-birch type² covers one-third of the commercial forest land in the Lake States (Findell *et al.* 1960, Stone and Thorne 1961, Stone 1966): 7 million acres in Minnesota, and 9.4 million acres divided fairly evenly between Wisconsin and Michigan.

The net volume of paper birch growing stock in the Lake States is about 1.6 billion cubic feet or about one-fourth as much as the volume of aspen (table 1). Both the net annual growth and the annual desirable cut exceed the annual cut by a large amount in every one of the Lake States. The total cut in the three States combined is only 16 percent of the desirable cut.

The sawtimber net volume is about 1.1 billion board feet (table 1). Better use is made of the sawtimber trees than the pole-timber trees. The annual sawtimber cut is 35 percent of the desirable cut.

Information for the remainder of the resource section deals only with Minnesota where the most recent survey was conducted

(Stone 1966). The paper birch forest type stands are located mostly on good to medium sites:

Site index ¹	Site class	Area (percent)
66+	Excellent	11
56-65	Good	34
48-55	Medium	36
38-47	Poor	19

¹ Site index expresses forest site quality as the height of dominant trees in feet at the age of 50 years.

The paper birch forest type stands are in fairly good condition, as indicated by levels of desirable stocking and other conditions affecting current and prospective tree growth. Thus, 29 percent of the areas are at least 70-percent stocked with desirable trees. Another 44 percent are 40- to 70-percent stocked with desirable trees, and only 27 percent are less than 40-percent stocked with desirable trees.

More than half (54 percent) of the Minnesota paper birch forest type stands are in the 30-to 50-year age groups. Seven-eighths of the paper birch growing stock volume on all commercial forest land is in pole-timber-size trees (5 to 10.9 inches d.b.h.).

¹ Names and dates in parentheses refer to literature cited.

² Defined roughly as forests in which quaking aspen, bigtooth aspen, or paper birch, or any combination of these species, comprises 50 percent or more of the stand.

Table 1. — Paper birch growing stock¹ and sawtimber² on commercial forest land in the Lake States³

State	Net volume	Net annual growth	Annual desirable cut	Annual actual cut
GROWING STOCK (Million cubic feet)				
Minnesota	768.5	28.0	19.7	2.5
Wisconsin	348.2	14.2	12.7	2.7
Michigan	438.0	20.6	14.9	2.4
Total	1,554.7	62.8	47.3	7.6
SAWTIMBER (Million board feet)				
Minnesota	448.3	26.4	22.2	7.8
Wisconsin	188.0	16.9	8.4	3.0
Michigan	460.0	26.6	18.5	6.3
Total	1,096.3	69.9	49.1	17.1

¹/ All live merchantable trees 5.0 inches d.b.h. (diameter breast height) and larger; volume measured from stump to a minimum 4-inch top diameter outside bark.

²/ All live trees at least 11 inches d.b.h. containing at least one merchantable saw log; volume measured from stump to a minimum 8-inch top diameter outside bark; International $\frac{1}{4}$ -inch rule.

³/ From Findell *et al.* 1960, Stone and Thorne 1961, Stone 1966.

Contrary to the overall Lake States trend, Minnesota shows a decreasing trend in annual paper birch cut, possibly because of declining use as fuelwood: 4.7 million cubic feet were cut for all purposes in 1936, 3.5 million in 1953, and 2.5 million in 1960, all from growing stock on commercial forest land.

Even though the annual mortality is as high as 4 million cubic feet, the paper birch growing stock volume in Minnesota has increased from 416 million cubic feet in 1953 to 768 million in 1962. Most of this paper birch resource is in the north central and northeastern sections of the State.

Climate, Soils, and Associated Trees

Paper birch grows in a climate characterized by short cool summers and long cold winters with long periods of snow on the ground (Fowells 1965). This species has many varieties and hybrids which, as a group, have a transcontinental range from Alaska through most of Canada, the Lake States, and New England to New York.

It grows on a variety of soils over a wide range of soil-moisture conditions either in pure stands or, more often, as part of a mixed species stand. In the Lake States, paper birch is commonly found associated with aspen, jack pine, balsam fir, and white spruce (Findell *et al.* 1960, Stone and Thorne 1961, Stone 1966).

Paper birch, being intolerant of shade, usually lasts only one generation in the natural succession, and is then replaced by more tolerant species (Fowells 1965). In the northern Lake States, however, it is a common component of the climax white spruce-balsam fir-paper birch forest type, possibly due to its ability to occupy bare areas such as those created by blowdowns in the stands.

Reproduction and Growth

Reproduction is mostly from seed although moderate stump sprouting can occur (Gilbert and Jensen 1958) especially after cutting or fire (Fowells 1965). The newly germinated seedlings are very fragile, and are sensitive to moisture, light, and seedbed conditions. Seedlings as well as the older trees require overhead light. The growth rate is high — many individual trees have a diameter of 8 inches after 30 years (Betts 1945). However, this species has a short life span.

Trees on poorer sites, site index 40, should be cut at the age of 60 years in Wisconsin (Cooley 1962) when the trees have reached a height of 44 feet. On the better sites, site index 80, cutting can be delayed until the age of 80 years when the trees may be more than 100 feet tall and 14 inches or more in d.b.h. Trees in mature stands on intermediate sites average 10 inches in diam-

eter and 70 feet in height (Fowells 1965). If cutting is delayed beyond the recommended ages, the growth rate soon becomes negligible and the wood deteriorates rapidly due to attacks by many enemies.

Enemies

A number of enemies can attack the tree. Stain fungi such as *Torula ligniperda* can cause red heart, which is characterized by wetwood (Campbell and Davidson 1941). Red heart affects 15 to 30 percent of the trees in mature stands (Brown *et al.* 1949). False tinder fungus, *Fomes igniarius*, and a clinker fungus, *Poria obliqua*, are the two most important rot-causing fungi that attack this tree (Fowells 1965). Discoloration and decay-causing organisms are frequently found together and interact (Shigo 1965).

Dieback, progressive dying from the treetop downward, is frequently seen in paper birch. This condition has been studied by a number of researchers. Dieback has coincided with a series of exceptionally dry summers and cold winters (Nash 1949), periods of high temperature and drought (Lortie *et al.* 1962), changes in chemical components in leaves (Lortie and Laforte 1962), fungi (U.S. NE Forest Exp. Sta. 1952), virus symptoms (Berbee 1957), and rootlet mortality (Greenidge 1953, Pomerleau and Lortie 1956). Cause-and-effect relations have been hard to prove, however. Tree injection experiments showed that three common elements of nitrogen, potassium, and phosphorus are not factors in occurrence of dieback (Morris 1951). No fungus or virus has ever been positively associated with birch dieback (Hahn and Eno 1956). Effects of dieback on the chemical properties of wood are not apparent (Timell 1957).

The bronze birch borer, *Agrilus anxius*, is often associated with dieback (Balch and Prebble 1940), and the borer may then cause the death of a tree that otherwise might have recovered (Barter 1957). Its attack usually begins in the crown and progresses downward into the bole as meandering galleries on

the surface of wood and in the outer layers of sapwood (MacAloney and Ewan 1964).

The forest tent caterpillar, *Malacosoma disstria*, can cause serious damage, especially if attacks are repeated. Annual growth may be reduced by as much as 86 per cent during the third year of complete defoliation (Barter and Cameron 1955).

Many animals damage this tree. Mice kill young seedlings by girdling (Stoeckeler

1955). Squirrels peel off the bark (Lutz 1956), and deer browse the leaves (Aldous 1952, Graham 1958).

A condition known as post-logging decadence often develops where the trees have been suddenly exposed by opening of the stands (Fowells 1965, Gilbert and Jensen 1958). The result is lowered vigor, reduced growth, dying back of twigs and branches, and sometimes even death of the tree.

Wood Quality and Properties

Paper birch wood has a fine even texture and uniform grain (U.S. Forest Prod. Lab. 1963). The wood cannot be separated with certainty from that of the other birches on the basis of either gross structure or minute anatomy (Panshin *et al.* 1964). The sapwood is white and 2 to 4 inches thick in mature trees, and frequently makes up nearly all of the wood in rapidly grown trees up to 10 inches in diameter (Betts 1945). The heartwood is light reddish brown (U.S. Forest Prod. Lab. 1963). Wood around the pith is often discolored and contains small checks, shakes, and pin knots; such wood is known as "heart center." Growth rings are frequently hard to see without a lens (Panshin *et al.* 1964). Wood is diffuse-porous. The larger pores are wider than the widest rays, and the pores are solitary or in multiples of two to several. The rays are so fine that they are often not visible to the naked eye. As in most hardwoods, fiber tracheids are short, 1.35 mm. long with a standard deviation of 0.15 mm.; and the vessel elements are 1.00 mm. long with a standard deviation of 0.26 mm. (Panshin *et al.* 1964).

Paper birch is moderately heavy (see specific gravity, table 2) when compared to all woods grown in the United States (Markwardt *et al.* 1961); yet it is generally lighter than either yellow or sweet birch (Panshin *et al.* 1964).

Physical and mechanical properties of paper birch (table 2) occupy intermediate positions in the ranges of properties of commercially important woods grown in the United States. Paper birch is moderately strong in bending strength and has moderate

stiffness and moderate weakness in compression, but large shrinkage and high shock resistance (Markwardt *et al.* 1961). The wood's light color and almost complete lack of odor or taste make paper birch desirable for many uses.

The wood is fairly easy to dry. Even in Alaska, the 4/4-inch lumber can be air-dried in one summer down to 25-percent moisture content (U.S. Forest Prod. Lab. 1963), and sapwood 1-inch turning squares can be kiln dried down to 10-percent moisture content in 2½ days (U.S. Forest Prod. Lab. 1956).

Workability has been variously rated as relatively easy with handtools (U.S. Forest Prod. Lab. 1955), and as average with no reference to tools (Markwardt and Wilson 1935). Planing and shaping properties are fair (Davis 1962). In spite of many woods being noticeably better in turning qualities, paper birch turns well enough to be used commercially in large volume.

In assembly by nailing, nail splitting can be a problem; but once nailed without splitting, the nail-holding ability of this wood is high (U.S. Forest Prod. Lab. 1963). Gluing difficulties have been variously estimated, ranging from "glues well" (Panshin *et al.* 1964) to "difficult to glue" (U.S. Forest Prod. Lab. 1963).

The wood stains and finishes satisfactorily (U.S. Forest Prod. Lab. 1963). Once the product is finished, its ability to "stay in place" during moisture changes in normal use without warping has been variously rated as poorer than average (Markwardt and Wilson 1935) to good (U.S. Forest Prod. Lab. 1963).

Table 2. — Physical and mechanical properties of paper birch at various locations (Markwardt and Wilson 1935, Kennedy 1965)

Test and property	Unit of measure	Place of growth of material tested					
		Wisconsin		New Hampshire		Canada	
		Green	Dry	Green	Dry	Green	Dry
Moisture content at test	percent	72.0	4.2	58.7	11.8	--	12
Specific gravity, weight oven-dry volume at test		0.473	0.582	0.494	0.568	0.506	0.571
Static bending							
Stress at proportional limit	p.s.i.	2,920	11,440	3,020	7,330	3,200	7,430
Modulus of rupture	p.s.i.	5,770	16,050	7,000	14,060	6,850	13,750
Modulus of elasticity	1,000 p.s.i.	1,013	1,814	1,328	1,744	1,450	1,870
Work to proportional limit	in.-lb.						
	per cu. in.	0.49	4.32	0.40	1.85	0.40	1.67
Work to maximum load	in.-lb.						
	per cu. in.	15.0	13.2	17.4	18.2	14.6	20.7
Impact bending, height of drop causing complete failure (50-pound hammer)	in.	45	24	53	48	42	47
Compression parallel to grain							
Stress at proportional limit	p.s.i.	1,640	6,140	1,630	3,620	1,670	3,710
Maximum crushing strength	p.s.i.	2,210	9,470	2,510	6,140	2,690	6,480
Compression perpendicular to grain, stress at proportional limit	p.s.i.	304	912	370	1,002	358	997
Shear parallel to grain, maximum shearing strength	p.s.i.	786	1,627	886	1,214	944	1,634
Tension perpendicular to grain, maximum tensile strength	p.s.i.	382	--	--	--	618	1,040
Hardness--load required to embed a 0.444-in. ball to ½ its diameter							
End	lb.	400	1,487	532	928	562	979
Side	lb.	486	1,278	632	996	620	972
Shrinkage from green to oven-dry condition based on green dimensions							
Volumetric	percent	16.3	--	16.0	--	13.8	--
Radial	percent	6.6	--	6.0	--	5.2	--
Tangential	percent	8.8	--	8.5	--	7.2	--

Chemical analysis of the wood reveals the following components (U.S. Forest Prod. Lab. 1963):

	Percent
Lignin	19.0
Holocellulose	77.0
Alpha cellulose	45.0
Total pentosans	23.3

Solubility in —	Percent
Alcohol benzene	2.8
Ethyl ether	1.3
1-percent NaOH	14.1
Hot water	1.5

Paper birch has a higher holocellulose and a lower lignin content than most other native species.

The United States as a whole cuts half of its wood into saw logs, a quarter into pulpwood, and one-tenth into fuelwood (U.S. Forest Service 1965). The Lake States reverses the saw log and pulpwood proportions — nearly half of its wood goes for pulpwood, almost a quarter for saw logs, and a quarter for fuelwood.

Data for Michigan in 1965 shows paper birch used in yet another proportion — half still is pulpwood, but fuelwood use at 30 percent is higher than saw log use at 16 percent.³ Veneer logs at 3 percent are in fourth place, with miscellaneous industrial products making up the remaining 1 percent. These use ratios reflect the small size of paper birch in the Lake States.

Pulpwood

Pulpwood is the most substantial use for paper birch in the Lake States; in 1965 pulpwood production was 55,359 cords (Horn 1966).

Use of paper birch as pulpwood is increasing in Wisconsin and Michigan, but not in Minnesota. This may be due to the fact that local supplies of the traditional pulpwood species have been depleted in Wisconsin and some parts of Michigan whereas Minnesota mills still have greater quantities of these species within easy reach.

Sticks as small as 4 inches inside bark at the small end are often acceptable if otherwise of sound quality (Davis 1953). Sticks are commonly 100 inches long. However, depending on the method of transportation, pulpwood can be delivered either in cordwood lengths of 4 to 8 feet, in log lengths of 12 to 24 feet, or in tree lengths (Panshin *et al.* 1962). Paper birch lasts in storage as well as aspen or balsam, but not as well as hemlock or spruce. It must usually be pulped within a year to avoid deterioration (Davis 1953).

Groundwood paper birch pulp has a low strength but a fair color (Hytinen and Schafer 1948). Up to 25 percent of this pulp can

be used in toweling and 30 percent in newsprint (Schafer and Pew 1942). It can also be used as filler stock in book papers (U.S. Forest Prod. Lab. 1963). Groundwood pulp yields are typically very high, about 93 percent by weight.

Chemigroundwood paper birch pulp is moderately low in strength and is usually blended with softwood groundwood and sulfite pulps to make newsprint paper (U.S. Forest Prod. Lab. 1963). Chemiground pulp yield varies between 80 and 95 percent by weight.

Chemimechanical cold soda paper birch pulp is comparatively low in strength, but has its use in mixtures with other pulps for box boards and book and newsprint papers (U.S. Forest Prod. Lab. 1963). Cold soda pulp yield varies between 80 and 95 percent by weight.

Neutral sulfite semichemical paper birch pulp is particularly bright and strong (U.S. Forest Prod. Lab. 1963). It is used in corrugating and coarse wrapping paper furnishes (Tech. Assoc. Pulp Pap. Ind. 1947), and it has been found to produce lithographic paper of good quality (U.S. Forest Prod. Lab. 1963). It has use as a substitute for chemical pulps in newsprint and other groundwood-sulfite papers. Newsprint paper has been made at the Forest Products Laboratory using 20 to 60 percent birch sulfite semichemical pulp together with varying amounts of spruce and birch groundwood. Semichemical pulp yield varies between 60 and 80 percent by weight.

Sulfate paper birch pulp seems to have the best overall strengths properties of any hardwoods (U.S. Forest Prod. Lab. 1963). It reduces readily with high yield and a strength equivalent to 75 percent of spruce pulp strength (Isenberg 1951). Finnish birch, a close relative of paper birch, is used to make sulfate pulp that competes with coniferous wood sulfite pulps in strength and is even more important in providing bulk, opacity, compressibility, smoothness, and absorption power to paper when used in mixtures with coniferous wood pulps (Alm

³ Personal communication from J. E. Blyth, North Central Forest Experiment Station, 1968.

1965). The paper birch sulfate pulp yield is 50 percent by weight (U.S. Forest Prod. Lab. 1953).

Sulfite paper birch pulp strength is almost equal to the strength of hemlock pulp, and is about 75 percent as strong in burst and 90 percent in tear as spruce sulfite (Tech. Assoc. Pulp Pap. Ind. 1947). Seasoned paper birch is preferred over green wood to avoid trouble caused by wax in the wood (Isenberg 1951). The wood reduces easily, with a normal yield of rather poor-colored pulp that, however, is easy to bleach (U.S. Forest Prod. Lab. 1963). The yield is 46 percent by weight (U.S. Forest Prod. Lab. 1953).

Chemical soda pulp can be made from paper birch also, and is fairly easy to bleach (Isenberg 1951). But it reduces with some difficulty (U.S. Forest Prod. Lab. 1963). The pulp yield is normal. (Isenberg 1951), 42 percent by weight (U.S. Forest Prod. Lab. 1953).

Thus, paper birch can be pulped by any process, and various types of papers can be made. Producers, however, usually prefer to deal with other species of trees that are easier to handle and peel (Davis 1953). When paper birch is used, it is typically mixed with other woods to make up the short-fiber content of paper.

Consumption of paper and board is increasing rapidly, with a projected demand for pulpwood by the year 2000 nearly triple that of 1962 (U.S. Forest Serv. 1965). Hardwoods are expected to make up an increasingly larger share of the pulpwood, with a projected 40-percent share of the total round pulpwood by the year 2000. The largest increase in demand is expected for sulfate and semi-chemical pulps, both processes for which paper birch is well suited. Thus, greater demand for paper birch pulpwood can be foreseen.

Fuelwood

Fuelwood is the second most important use group for small-sized paper birch. One of the advantages of dry wood as a fuel is that it ignites readily and gives a quick, hot flame (Panshin *et al*, 1962). Paper birch has these characteristics to a high degree due to the

nature of its bark structure and high heat value. In addition, paper birch sticks are attractive, and consequently they find use in the limited market of luxury fireplace wood.

Although the demand for fuelwood is still substantial, it is declining (U.S. Forest Serv. 1965). During recent decades oil, gas, coal, and electricity have been increasingly substituted for wood, both for home cooking and heating and for industrial uses.

Saw Logs

The larger paper birch trees are cut into saw logs and veneer logs. Several years ago the principal paper birch lumber source in the northern Lake States was the so-called "side lumber," a byproduct of crosstie manufacture (Davis 1953). Today this source is less important, and lumber is a primary product cut from the log. In Vermont, a large portion of the ungraded hardwood lumber is paper birch; it is sawed "through and through" and sold round edge (Whitmore 1962). The lumber is used for boxes and crates (U.S. Forest Prod. Lab. 1963), pallets, picket fencing, knotty paneling (Davis 1953), and so on.

Lumber used in containers has dropped substantially in recent years, largely because nailed, lock-corner, and wirebound boxes have been displaced by corrugated and other fiber boxes, metal and fiber drums, and multiwall paper bags (U.S. Forest Serv. 1965). However, use of wood for pallets is growing steadily. A substantial rise is also projected in total use of lumber and panel products in construction. Paper birch is good for pallets and panel products.

Veneer Logs

The best quality, large-size paper birch trees can be cut into veneer logs. Until recently veneer logs have had to meet strict quality standards as to size. All general veneer grade logs have had to be at least 12 inches in diameter and at least 8 feet 6 inches in length (Peterson 1965). However, new lathes with supporter rolls, and chucks with changeable spindles have made it possible to cut logs down to 3- or 4-inch cores, so that smaller diameter logs can now be used.

Saks (1951) has suggested that since the most popular sizes turned out by the veneer and plywood industry are 7-foot and 8-foot panels, log lengths to produce such panels should be 7 feet 6 inches and 8 feet 6 inches. The standard veneer is used to make plywood, furniture (U.S. Forest Prod. Lab. 1963), cabinets, and school seating (Davis 1953) among others. Paper birch is suited for these products.

Specialty veneer products form an interesting group. Smaller segments of the tree

can often be used for these products than for standard veneer products. For example, wooden match box cover veneer can be made of 100-inch paper birch bolts with a diameter of 8 inches or more at the small end inside bark. Some specialty veneer products manufacturers even accept bolts 6 inches in diameter and 50 inches in length (Davis 1953). Other specialty veneer items include round cheeseboxes, and die-cut products (fig. 1). Paper birch is a preferred species for die-cut products such as ice-cream sticks, picnic

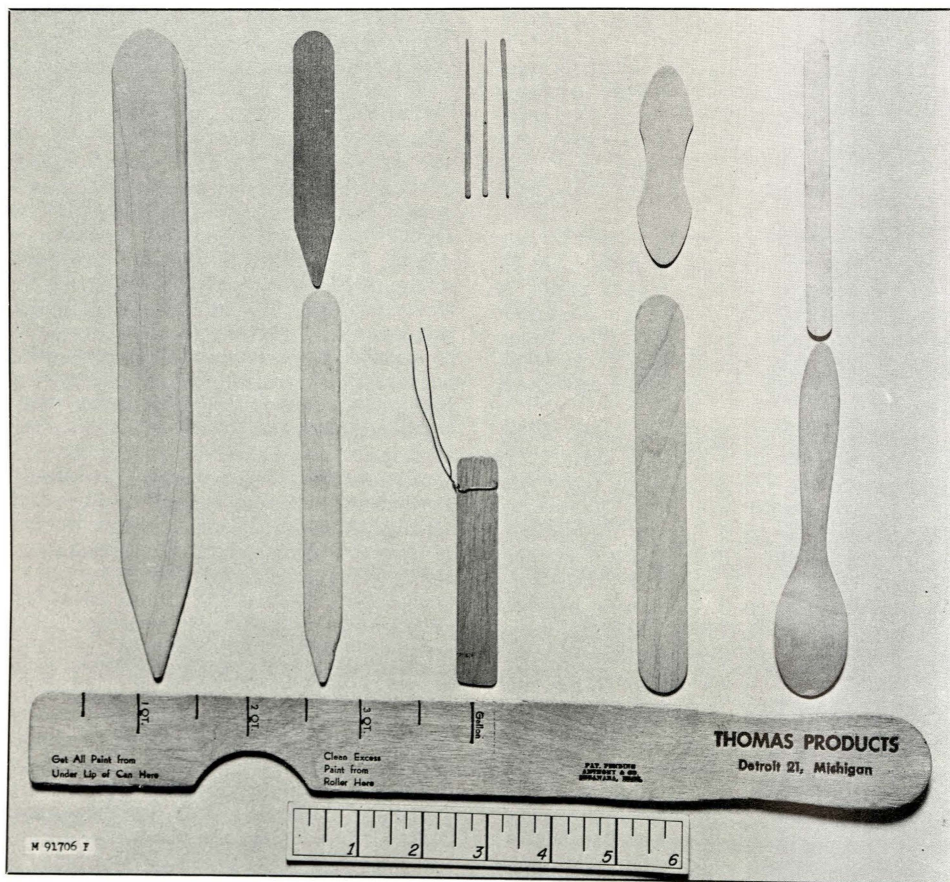


FIGURE 1. — Typical die-cut products made from rotary veneer of paper birch.

spoons plant markers, swab slats, tongue depressors, and toothpicks.

The value of hardwood logs required to meet projected demands in the year 2000 for hardwood veneer and plywood is estimated at 3.3 times that of the year 1962 (U.S. Forest Serv. 1965).

Turning Products

A considerable quantity of paper birch is used for miscellaneous turning products in the northern Lake States, but even more is used for that purpose in New England. Maine, New Hampshire, and Vermont, the best paper birch area, have more wood-turning plants than all other states combined (Panshin *et al.* 1962). Bolts 50 and 100 inches long and down to 6 inches in diameter are acceptable if they are sound, smooth, and straight (Davis 1953). Turning products (fig. 2) include bobbins, clothes pins, and spools (U.S. Forest Prod. Lab. 1963); broom handles, chair rounds, dowels, mop handles, and shuttles

(Davis 1953); and shoe pegs and shoe shanks (Betts 1945).

Crossties

Until recently small quantities of paper birch have been used by portable mills in the northern Lake States for making crossties (Davis 1953). Logs with a 9-inch minimum diameter and an 8-foot length are required (Peterson 1965). These ties, class T, have to be treated with preservative (Panshin *et al.* 1964).

Other Products

Other uses for paper birch include mine props in Alaska (U.S. Forest Prod. Lab. 1963), toys, and carved articles. The bark was used by northern Indians for canoes and even today various small articles are made from the bark. At least one mill in the Lake States has used paper birch in the manufacture of particleboard.

Prices

A knowledge of prices is essential to landowners and managers in their timing and choice of products to be harvested. The buyer, too, must know the latest prices of such products in his area and must consider his own costs as well as the price he will receive for his finished product such as lumber. Prices of saw logs, lumber, and so on vary considerably by locality and with time, and therefore offer an opportunity for profit as well as the chance of a loss.

Some Recommendations for Additional Research

The use of any one species such as paper birch for a product depends on its availability in needed quantities, the costs of production, and its suitability for the product compared to other woods and substitute material. Further research should be conducted with these points in mind.

The existence now or in the near future of large sawtimber-size stands could be

Paper birch veneer logs bring the highest prices, but require best quality large-size trees. Paper birch veneer log prices span the gap between the higher yellow birch prices and the lower aspen prices in Minnesota. Paper birch pulpwood prices, on the other hand, have in the past been only about half as high as spruce pulpwood prices and only slightly higher than aspen pulpwood prices. Paper birch saw logs are next highest to veneer logs in price.

studied. Do we now have such stands in sufficient quantity in some as yet untapped region, or will they be created by ingrowth soon, to justify expanded veneer and saw log operations?

The economic aspects of pulping paper birch by various processes have not been nearly as fully reported in the literature as the technical aspects and should be studied.



FIGURE 2. — Some types of small turnings made from paper birch in New England.

Lumber quality of sawtimber-size paper birch trees is another subject about which not enough is known.

Fiber and particleboard industries are potential users of the poletimber-size stands as well as some of the sawtimber-size stands. This use should be investigated, especially for paper birch mixed with aspen with which it frequently forms mixed stands over much

of its range. Use of paper birch with its bark in insulation board and particleboard could also be explored.

Additional investigation is needed on controversial points concerning the quality and properties of paper birch wood, particularly its workability, gluing characteristics, and ability to stay in place.

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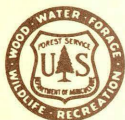
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